Oakley Sound Systems

5U Oakley Modular Series

TSL - Transistor Superladder Voltage Controlled Filter

PCBs Issue 2, 3 & 3.1

User Manual

V3.1

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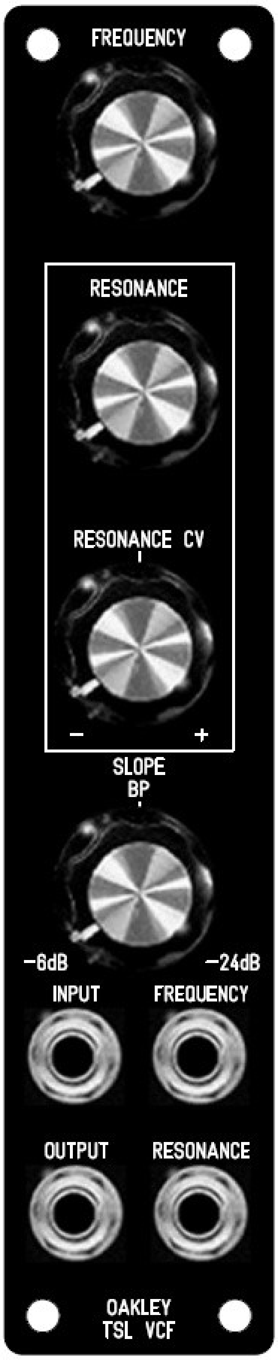
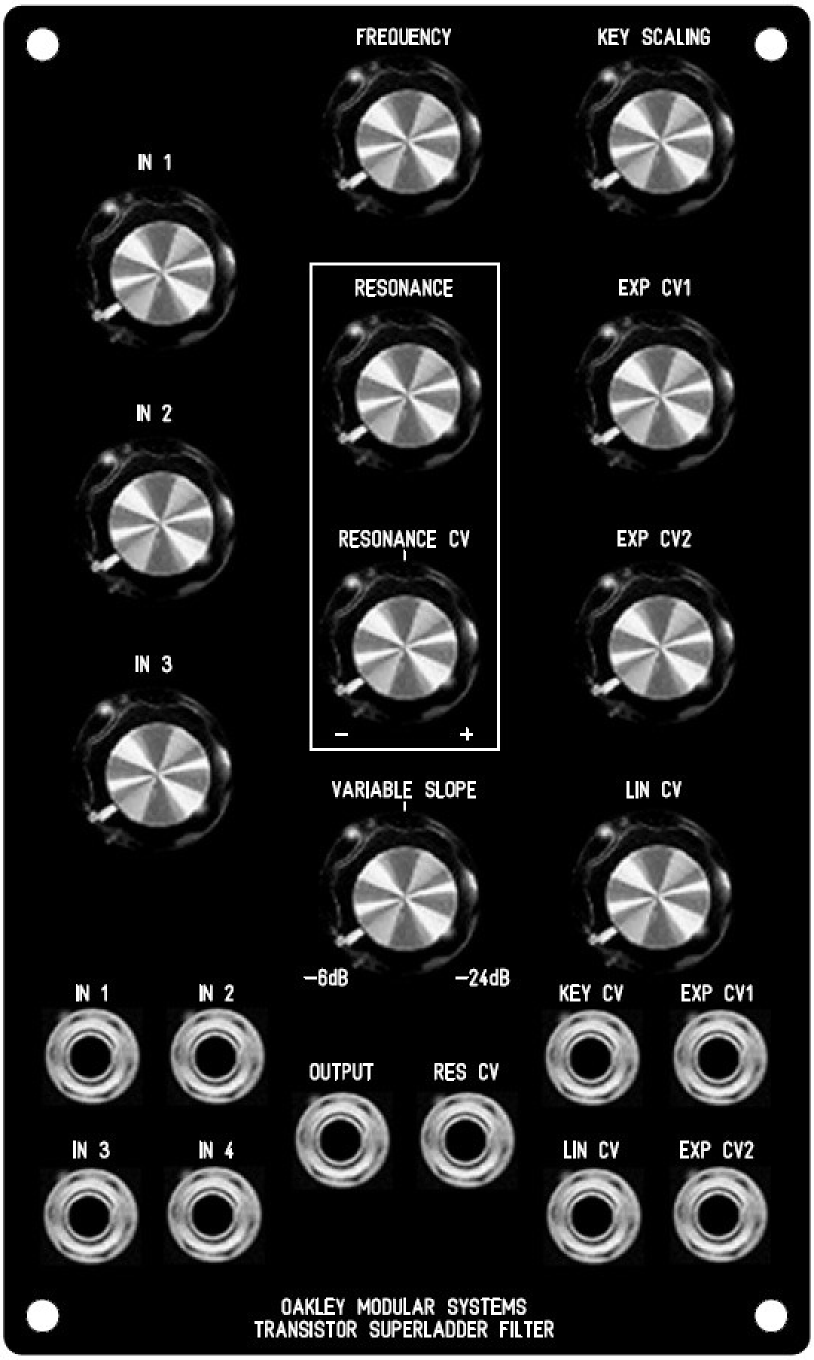


The suggested panel layout for the 1U filter core in MOTM format.



The suggested panel layout for the full 3U version of the Transistor Superladder module in MOTM format.

Introduction

This is the User Manual for the issue 2 and 3 Transistor Superladder 5U module from Oakley Sound Systems. This document contains an overview of the operation of the unit, the history of the various board issues, and the calibration procedure

For the latest Project Builder's Guide, which contains a basic introduction to the board, a full parts list for the components needed to populate the boards, and a list of the various interconnections, please visit the main project webpage at:

http://www.oakleysound.com/super.htm

For general information regarding where to get parts and suggested part numbers please see our useful Parts Guide at the project webpage or http://www.oakleysound.com/parts.pdf.

For general information on how to build our modules, including circuit board population, mounting front panel components and making up board interconnects please see our generic Construction Guide at the project webpage or http://www.oakleysound.com/construct.pdf.

The Oakley Transistor Superladder Module

The Transistor Superladder or TSL is a voltage controlled filter based on the classic ladder topology as patented by Dr R A Moog in the 1960s.

In this module the cut-off frequency and resonance are both voltage controllable. The Superladder VCF module has a variable shape output. It incorporates a feature first seen on the Oakley Orbital prototypes. A single pot allows you to vary the output from one pole low pass to four pole low pass via band pass in the middle.

The Superladder's output is what we call 'Q compensated'. This means that the output volume will not drop significantly when you turn up the resonance pot. This design uses two inbuilt VCAs to achieve voltage controlled resonance without the hassle.

At high levels of resonance the Superladder will self-oscillate across most of the audio band and thus can be used as a sine wave voltage controlled oscillator.

The module design uses a discrete transistor core which means it does not clip the signal abruptly but saturates smoothly. This allows the TSL to sound very different depending on the input signal level. When used with signals below 1.5V peak the TSL will sound clean and bright. However, take your signal levels above 1.5V peak and it will start to take on a more strident tone particularly at higher levels of resonance. Coupled with the variable slope control, this sensitivity to input level means the Superladder can produce a wonderful array of different tones.

The voltage controlled filter, or VCF, may be built as a 1U filter core or as a complete 3U filter system. The 1U 'Filter Core' format is our way of handling filter modules. Although the 1U module can be used as a filter module on its own, it is expected that users will make use of external mixers to control CV and audio levels going into the filter. In this way, you will be able to have a collection of space saving 1U filter cores that can be used with any generic mixer module. The Oakley Multimix is an ideal choice for a handy mixer module.

This latest version of the module accommodates either our standard Oakley/MOTM power header or a Synthesizers.com power header.

Also available from Oakley Sound is the Diode Superladder or DSL. This is similar in function to the Transistor Superladder but uses diodes instead of transistors in the filter core and sounds considerably different.

The Filter Core Idea

As you have read this module can be made into either a standard 3U wide module, or as a compact 1U filter core module.

The Filter Core idea has come from the fact that many of our customers were buying different filter types, eg. they may have an MS-20 clone, a Moog ladder filter and an SVF. Each filter type gives a different sound so its worthwhile having a few in your modular set up. However, each filter module also has its own input mixer for audio and an input mixer for CVs. This adds to panel real estate and soon your modular is filling up very quickly. While this does look very impressive, it does mean that, in many patches, you have a lot of redundant electronics in your modular.

Step forward the 'filter core'. This is quite simply a 1U module that contains only the filter and a few important front panel pots. All the audio and CV mixing is done externally with a dedicated mixer module, like the Multimix. The good thing about this is that any unused filter module is only 'wasting' 1U of panel space. So you can afford to have many different flavours of filter without the additional cost and panel space of mixers.

However, as with all things, there are disadvantages too. The lack of inbuilt mixers mean that you will need to get more dedicated mixer modules. But remember that these relatively cheap mixer modules can be used for **any** mixing or level controlling within your modular. Thus, you have more flexibility, at the expense of a little more patching.

The great thing about the Oakley Filter Core modules is that they will all be designed so that they can still be used in the full format design. All the Filter Core modules will have input summing amplifiers built onto the PCB. You won't be using these circuits in the 1U format, but they are there if you want to go for the larger 2U or 3U designs.

A bit more about signal levels

The Superladder is a non linear device. This means it does not process small input signals in the same way as it processes large input signals. In other words, the Superladder will sound different depending on how loud the input signal is.

All electronic circuitry is, to a certain extent, non linear. That is, all circuits impart some sort of distortion to the signals that pass through them. For the most part a good audio circuit will be designed so that this distortion is as small as possible. You'll see words like 'transparency' and 'clarity' being used. In engineering we tend to talk about the various distortion figures and bandwidth accuracy where, respectively, the lowest and flattest values would be required.

However, in musical instruments different types of distortion can be useful in creating new timbres and subtle textures. Level dependent distortion is very prevalent in these types of circuits. That is, the input signal level affects the way the signal itself is processed by the circuitry. In most cases this involves some sort of signal deformation as the instantaneous signal level increases in value. And that deformation usually increases as the signal level increases.

The transistor ladder distorts the signal in a complex way but it does so in a way that is musically interesting. Some ladder filters impose their sound not only by non linearities in the ladder but also in input and output circuitry. In the Oakley TSL I have tried to keep as many non linearities as possible to the ladder core itself and the rest of the circuit as clean as possible.

The moment you apply a signal to the TSL it starts to distort the waveform. The amount of distortion is negligible at lower levels of input signals but becomes more and more pronounced as the signal level rises. The levels at which signals become noticeably affected is normally called overdrive. The Superladder will overdrive with an input signal of around 1.5V peak but this does depend on input waveform, cut-off frequency and resonance settings. Overdriving the module, even for extended periods of time, will not harm it in any way.

Inserting the VCO signal directly into the 1U Superladder's input socket will assuredly overdrive the module. You'll notice that the sounds you get from it will be different to the usual transistor ladder sound.

It is therefore important that to get the best out of the Superladder you need to be able to control the input signal level. And if you have a Filter Core TSL then the best way to do this is with a mixer module. However, remember that when two, or more, signals combine you will get peaks that exceed that of the individual signals. This is why is useful to have a mixer with a level indicator.

The Superladder will self-oscillate and give you a sine wave output of around 2V peak. Clearly the effect of this self-oscillation on any input signal will depend on the input signal level. With a low value signal level the self-oscillation will dominate. Whilst with a large input signal the affects of the self-oscillation will be less.

The Superladder Legacy

The Superladder (SL) design was spawned by a project called the Walshbank. This was a complete analogue monophonic synthesiser that incorporated a voltage controlled digital oscillator that used an additive process to generate complex waveforms. The synthesiser also featured a voltage controlled ADSR, a flexible analogue VCF and a fairly traditional VCA. The VCO was a very big project on its own, so I decided to separate the VCF out and make it into a PCB project that people could build themselves. This was the first Superladder and it was released in late 1999.

The Superladder did various things that had not been done before to my knowledge at the time. Firstly, it sported a one pole output, a bandpass output and a four pole output. Secondly it could be built into either a diode ladder (like a TB303) or a transistor ladder (like a Moog). Thirdly, it incorporated a Q compensation circuit that kept the volume of the output fairly constant as the resonance was changed. Of course, as time passed I realised that I had not been the first to use these ideas, but I still think it was the first time that all three had been available in one design.

The issue 1 boards, the SL-1, were a relative success - I managed to cover my costs, which was all that I could ask for. However, there were some mechanical problems with fitting the board into a MOTM panel and rack rails, so I decided to make an issue 2. The SL-2 used a similar circuit, but made it easier to wire up and made it more MOTM compatible.

Both the issue 1 and 2 boards used the 2SC1583 matched pair in the differential amplifiers and the exponential converters. However, these were becoming harder to source so I needed to make a new issue board. Issue 3 used the more common CA3046 NPN array and op-amps in the differential amplifiers. It also featured a change in the way the Q-compensation worked; the level compensation circuitry was now fitted at the input to the filter core as opposed to after it. This was a big change in circuitry and the issue 3 boards sounded slightly different. I would say that the new board sounded better, it was cleaner and less noisy. However, I am waiting for the day when issue 1 Oakley boards are talked about in hushed tones as being the best.

All the issues so far used Omeg pots. These UK made pots were quite popular at the time and had a good reputation. However, my own experience was proving to be less than perfect. In particular, I had one batch that was very poor, with many units having to be returned. At great expense I began the slow roll out of a series of new designs that used the more expensive Spectrol 248 pots. These superior pots would prove to give excellent results and, so far, have shown good longevity.

Issue 4 Superladder PCBs and modules used Spectrol pots throughout. There were also some subtle differences in circuitry, but not much, and mostly to allow for easier wiring.

Issue 5 was being designed as I decided to take a break from the ready made modular market in 2005. It was laid out on my CAD system and only one board was ever made. It did, however, sow the seeds for the next iteration of the Transistor Superladder board, and its use of the THAT300P NPN array proved very successful. The premise of this design was for a RoHS (lead free) compliant Superladder. RoHS meant that we could no longer use the non compliant and now obsolete CA3080 and CA3046 devices. The THAT300P fitted the job of the core array perfectly. In fact, it's actually better than the CA3046 it replaced.

The CA3080's job in the SL-4 board was to control the depth of one of the incoming CVs, usually the envelope generator for velocity control. However, it was easier to remove the function from the module, rather than trying to find a RoHS alternative to the CA3080. The CV controlled EG depth was really a hangover from the Walshbank days, and our ADSR module already had a CV controlled level built into it. This partial loss of functionality started me thinking about the way these rather extraneous functions are handled, and so the filter core idea was formed.

Issue 6 was therefore never formally created. Instead, the design fragmented. The next Superladder, designed in September 2007, was thus labelled issue 1 Filter Core and concentrated solely on the transistor variation of the design. It was essentially the first of the transistor Superladders and I tend to refer to it as TSL-1.

In TSL-1 I removed the diode variation because I felt that the changes in the differential amplifiers and the feedback paths that had so benefited the transistor version since issue 3 had not done the same to the diode version. Simply put, I thought that since issue 3 the Diode Superladder did not sound as good as it had. In particular, the overdrive characteristics were not as predictable as the older designs and in issue 3 and 4 there were occasional instabilities when the resonance and frequency CVs were changed quickly. However, it was clear after the overwhelmingly positive response to Thomas White's popular You Tube Diode Superladder video that not everyone agreed with me.

So, in the Summer of 2010, I redesigned the Diode Superladder. This new issue 1 was to be a cross between the old issue 1 and issue 5. It used discrete differential amplifiers like issue 1, but used the Q compensation circuitry of issue 5. But after building the first prototype and testing it out I was very disappointed with the overall sound and performance of the module. It simply did not deliver the sound I was looking for. Somewhat disgruntled I shelved the project.

A month or so later I decided to have another bash. Rather than just tweak my previous efforts, I started from scratch and came up with, what I hope, is a unique design. After some exhaustive testing I finally settled on the component values that gave me the sound I wanted. This was the issue 2 Diode Superladder or DSL-2..

With the DSL-2 there are a great many differences compared to the previous versions. Q compensation is performed in a similar fashion to that of the early Superladders, that is, it acts on the output of the ladder core and not on the input. However, the implementation is completely different. And instead of two differential amplifiers, there are now three, one for each of the two rung outputs, and one for the resonance pathway. I have also added a fifth rung to the ladder allowing five pole filtering.

I think, in issue 2 of the Diode Superladder, I have achieved a great sounding diode ladder filter with an excellent performance and a great sound.

But development had not stopped on the Transistor Superladder. Issue 2 arrived in Autumn 2010. The TSL-2 was similar to the first issue but I now added the all important MU power connector. This allowed for easy integration into Synthesizers.com systems.

I didn't know at the time but the TSL-2 was the last Oakley PCB to be fitted for Spectrol pots. Vishay had bought out Spectrol some years earlier and had been changing the build quality of this once excellent pot. Newer Vishay 248 pots were expensive, had variable rotational torque and seemed less reliable. Because of this Paul Darlow had moved over to using the equivalent BI TT P260P pots for all his ready made builds. The BI pots were good devices but were again quite expensive and rather difficult to source.

Late in 2010 we decided to move the whole PCB range over to Alpha 16mm pots. Alpha pots are completely different in terms of pin out, shape and size. So the move to yet another type of pot involved considerable changes to the PCB layouts of all the Oakley 5U modules. Early in 2012 the last of the TSL-2 boards were built up and sold so it was time for a new version of the Transistor Superladder. TSL-3 features the new 16mm pot footprint as well as the inclusion of the Sock4 socket board. The SockX boards allow for faster module builds and thus the resultant reduction in overall costs. It also gives the module a tidier look.

TSL-3 also has a few changes to the circuitry. One of these includes an optional buffer circuit in the feedback portion of the ladder filter.

Trimmers

There are four trimmers, or presets as we used to call them in the UK, on the PCB. You do not need any special equipment, other than a decent voltmeter, to set these correctly. However, a digital tuner, or a VST tuner plug in, is very useful for setting the V/octave trimmer if you have the 3U version of the Transistor Superladder.

You should use a proper trimmer tool or a fine blade jeweller's screwdriver for adjusting the two multiturn trimmers. Vishay and others make trimmer adjusters for less than a pound. The two 6mm round trimmers need a small electrician's screwdriver.

There are quite a few trimmers on the PCB. Run through them in this order only.

TUNE: This adjusts the filter's cut-off frequency. Set this so that the filter's FREQ pot covers your chosen range. I would normally place this in the middle position for now, that is 10 turns or so, from one of the end points.

OFF1: This should be done with a scope or digital voltmeter (DVM). Monitor the output voltage of U1 pin 7 with respect to ground. Turn the resonance up full and set OFF-1 so that the voltage is as close to zero as you can get it. +/-50mV or so. Turn the resonance down, and check that it is still nearly zero volts.

OFF2: Listen to the 4 pole low pass output. Set the Resonance and Frequency pots to their mid positions. Now connect a triangle wave signal, about 500Hz at 5V p-p, into the RES CV socket and turn the RES CV pot to about 3 o'clock. You should hear the 500Hz signal through the low pass output. Adjust OFF2 until the sound becomes as low as possible - you will not get rid of it completely though.

BAL: Set the filter into self oscillation by turning the resonance pot all the way up. Listen the the main audio output with no input signal applied. Adjust the frequency pot until the frequency heard is about 880Hz or so. The precise frequency is not important, it just needs to be not too high or not too low. Now adjust the BAL trimmer until the sine wave sounds pure. You will notice that on each side of the ideal point the sine wave gets an extra harmonic and at extreme settings the pitch will actually drop.

TWEAK: Adjust this trimmer so that the filter just breaks into oscillation when the RES pot is moved to around 80% of its maximum setting. Alter the FREQ pot over its whole range to check whether you are getting a good frequency range of oscillation. If you set TWEAK too low, then the filter may only oscillate over a very small range.

V/OCT: This adjusts the scaling (or sensitivity) of the exponential inputs.

If you have the 1U 'Filter Core' version of this module there is no need to adjust this. Simply leave it in its middle position. You will be controlling scaling with your connected external mixer module. The nominal input sensitivity is 0.7V/octave.

For the full 3U module you have a dedicated KEY CV socket. In a perfect world V/OCT should be adjusted so that there is an octave jump in cut-off frequency when the KEY CV input is raised by one volt and the KEY SCALING pot is turned fully up.

Turn the key scaling and resonance pots fully up and let the filter oscillate. Then connect the KEY CV socket to the 'keyboard CV' out of your midi-CV convertor or analogue keyboard.

Play an A on your keyboard and adjust the FREQUENCY pot so that the filter gives out a sine wave like signal of around 880Hz. Now play the A note one octave higher than you were pressing. By adjusting TUNE and V/OCT you should aim to get the higher A to make the module give out 1760Hz, ie. double 880Hz. However, any change in V/OCT will also change the lower note as well as the higher note. So you will have to move back and forth between altering TUNE and V/OCT until you get the octave spread you require. Remember though that the Transistor Superladder will not be able to be made to track perfectly over as wide a range as your Oakley VCOs. As such, even if you have achieved a perfect octave spread with your two A notes, you won't be able, for example, to hear a perfect octave spread from two similarly spaced A notes a couple of octaves up. However, since the action of the Superladder is, for the most part, to filter and not to act as an oscillator this lack of perfect scaling should not be a problem.

BPA: Listen to the BP output so set the SHAPE (or VARIABLE SLOPE on the 3U module) pot to exactly central. Turn the frequency pot up quite high, connect a lowish frequency square wave to the audio input. Adjust BPA until the signal becomes ‘fizzy’ and loses the lower harmonics. On a scope, you will see the waveform will become a series of spikes and lose the square wave’s top and bottom levels. It’s easier to do than explain it.

Final Comments

I hope you enjoy using the Oakley Transistor Superladder module.

If you have any problems with the module, an excellent source of support is the Oakley Sound Forum at Muffwiggler.com. Paul Darlow and I are on this group, as well as many other users and builders of Oakley modules.

If you have a comment about this user manual, or have a found a mistake in it, then please do let me know.

Last but not least, can I say a big thank you to all of you who helped and inspired me. Thanks especially to all those nice people on the Synth-diy and Analogue Heaven mailing lists and those at Muffwiggler.com.

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